Project Title: Development of Simple Dust Measurement Techniques to Aid in Long-Term Dust Reduction Program for Almond Harvesting Operations Using Drone Technologies

Project No.: 18.AIR3A.Capareda

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Objectives:

1. Quantify visible dust concentrations using total suspended particulate (TSP) data during almond harvesting,
2. Develop a correlation between dust dispersion (extent of dust travel with speed) with weather conditions during harvest operations
3. Evaluate several quick measurement techniques that will provide measurable PM concentrations such as opacity, real-time image analysis and laser scattered particulate counter during almond harvest operations,
4. Determine dust level through significant changes in machinery adjustments or designs, and
5. Identiy various best management practices during almond harvesting that will impact overall dust reduction strategies in the valley

Interpretive Summary:

This project first evaluated TSP concentrations emissions between an old and new harvest machinery while varying various machine adjustments to reduce dust levels during actual harvest operations. The newly identified simple methods of visible dust measurements were used including drones that carry PM sampler to report on TSP concentrations. The research then proposes the current emission factor for old machinery as well as new ones.

The project then developed a simple correlation between dust migraton with weather conditions during harvest operations via dispersion modeling and video capture methods by drones. The project defined three levels of weather condition based on windspeed as Low (L) (0.5-2 m/s), Medium (M) (2-5 m/s) and High (H) (>5 m/s).

This project evaluated various quick measurement techniques to aid in long-term dust reduction program for the almond industry. The project evaluated four techniques and recommended the use of three methods as follows:

a. EPA Method 9 or called Visual Emissions Evaluation

b. EPA Alt 082 or digital opacity
c. Laser PM Counter
d. Opacity meters placed in the orchard floor

The project then reported the baseline TSP concentrations as well as correlated opacity measurement via EPA Method 9 and Alt 082. The project has recommended a baseline TSP concentrations established on Year 1 as a guide to report on the progress against the goal of reducing harvest dust by 50% by the Year 2025. While the project attributed a large contribution on dust reductions on the type of harvest machinery used, other factors such as orchard floor management, traffic management and soil types come into play. The project then proposes to develop a more comprehensive analysis of all these contributions and provide report of accurate TSP or opacity emissions level in the valley during harvest operations in the next few years. The project hopes to combine all previous work in the update as well as new best management practices that are identified in the years to come. The group also will look at other mapping and survey data to validate the yearly update of TSP levels.

The project has established newer dust reduction levels for the current year of work using visible dust concentration levels. These new values of opacity and drone TSP data will be used as guide for future research dendeavors.

Finally, the project hopes to develop a more robust visible dust emission factors based of decades of harvest emissions work in the valley.

Materials and Methods:

The project identified at least four simple dust measurement techniques to measure visible dusts. These techniques are either EPA approved or measurement techniques and easily correlated with EPA approved methods, without sacrificing the quality of information. The hypothesis is, there are similar methods for dust evaluation without the need for expensive and tedious setting up of facilities and equipment. We will evaluate the following methods on the first year and carry over potential methods in succeeding years or evaluate other methods suggested by the industry experts.

a. EPA Method 9 or also called Visual Emissions Evaluation (VEE)
b. EPA Alternative Method 082 or also called Digital Opacity Compliance System (DOCSII)
c. Opacity Meters
d. Laser PM Measurements using Drones or UAVs

EPA Method 9 Visible Emissions Evaluation (VEE)

EPA Method 9 (EPA Method 9 and 22, 1993) is an EPA approved method that determines the value of opacity for dust sources. It is applicable to any NSPS (New Source Performing Standrds) or SIP (State Implementation Plan) sources with an opacity standard. The observer must demonstrate the ability to measure plumes in the field and certified by EPA (EPA approved designated office) every 6 months. The observer views the plume from a position that minimizes the line of sight through the plume to minimize positive bias. The sun is the light source and it is required to be at the observer's back. The viewing times is momentary observation every 15 seconds for a given period by the standard. Observer records all data.

EPA Alternative Method 082 Digital Camera Opacity Technique (DCOT)

EPA Alt Method 082 is a variation of EPA Method 9 where instead of using human eye, observer captures the plume using approved digital camera or digital video camera. This method follows ASTM D7520 Digital Camera Opacity Technique with a few restrictions (ASTM D7520, 2016). The method also required a trained and certified operator. A third party (duly EPA certified) processes the data and reports a more accurate opacity reading based on numerous calibration techniques. The study uses Canon Powershot SXH60 for still images and Sony Handy Cam HDRCXX for continuous video recording.

Opacity Meters

Opacity meters are devices that measures the visible dusts and reports the opacity directly. One installs the unit exactly where one generates dust plume. During almond harvesting operations, the operator install the opacity meters on the next row where the dust accumulates. This technique required the operator to move the opacity meters each single pass of the harvester. The study uses the PMX particulate monitor and OPAX-1000 opacity sensor (EMX Industries, Cleveland, OH).

Measurements of Dusts Using Laser PM Instruments Mounted on Drones

This technique made use of attenuated laser beam measurements of visible dusts mounted on drones. The instruments are very similar to EPA approved Federal Reference Methods (FRM) PM samplers. For this study, we used AEROCET 831 (by METOne). The Aerocet 831 is a completely portable, full–featured, battery operated, handheld mass monitor. A mass monitor simultaneously provides five important mass ranges including TSP. This small lightweight instrument (28 oz), is the perfect tool mounting in drones and follows the harvester in real-time.

Site Selection. The orchard used for this study is located on the northeast corner of Road 84 and avenue 88 in Dinuba, California. This is a 120-acre orchard planted on east-west rows shook on September 8, 2018 and owned by Dan Visser.

Harvest Machinery Used

The harvest machinery used were all from Flory Industries (c/o Mike Flora). The control was Flory 480 and the low dust harvester was Flory Self Propelled 8770 Model. Efird Industries and Flory Industries provided the operators.

Experimental Design

There are six (6) treatments identified int his study as shown in Table 1. We replicate each treatment three times and all conducted simultaneously

Table 1. Treatments and variables used during actual almond harvest operations.

No.	Speed	Head Height	Fan Speed	Machine Setting	Treatment ID
1	3 mph	½” down	900 rpm (std)	Almond HP	T1A, T1B, T1C
2	3 mph	¼” up	900 rpm (std)	Almond HP	T2A, T2B, T2C
3	5 mph	¼” up	900 rpm (std)	Almond HP	T3A, T3B, T3C
4	5 mph	¼” up	600 rpm (enviro)	Almond HP	T4A, T4B, T4C
5	3 mph	¼” up	600 rpm (enviro)	Almond HP	T5A, T5B, T5C
6	3 mph	¼” up	No Fan	Almond HP	T6A, T6B, T6C
7	3 mph	¼” up	900 rpm (std)	Almond HP	C1A, C1B, C1C
8	3 mph	¼” up	900 rpm (std)	Almond HP	C2A, C2B, C2C

Data Analysis and Correlations. The project correlated the TSP baseline data from the PM sampler with the opacity readings from EPA Method 9 and Alt 082 as well as the opacity meters. For dust migration studies, the project simply made use of EPA recommended AERMOD dispersion modeling tool to map out dust migration and correlate that to those real-time video images captured by the drones.

Results and Discussion:

1. Visible Dust TSP Concentrations During Almond Harvest Operations

The project evaluated all TSP measurements during previous harvest operations and correlate that with the current year of work. Figure 1 shows the comparative analysis of baseline visible dust measurements in previous years of study. TSP concentrations from collective data by Faulkner (2010) and Capareda (2017) shows the average TSP emission factor to be around 53.6 lba/acre (6,300 kg/km^2) while those for all new machineries is around 22.4 lbs/acre (2,500 kg/km^2) using rounded nominal values. New machine whose settings are not optimized may have higher emission factor as shown (39 lbs/acre or 4,412 kg/km^2). The current level of TSP concentrations during almond harvest operations will depend on the inventory between old and new harvesters. For example, if there is a 50:50 split between old and new harvesters, we expect the current TSP level to be the average of the two (4,400 kg/km^2) which is quite equivalent to the emission factor of a new harvest machinery whose settings are not optimized.

Hence, the baseline TSP concentrations for the year 2018 was estimated based on the inventory from various sources and the development of a spreadsheet simulation software to keep track of yearly TSP levels.

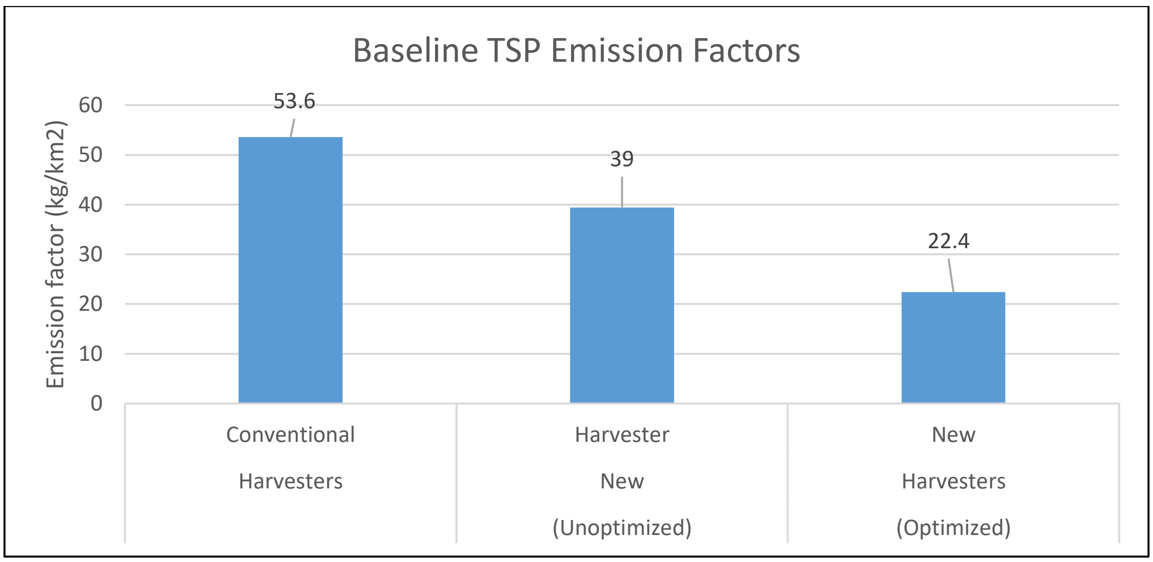


Figure 1. Proposed baseline TSP values for old and new machines.

Proposed 2018 TSP Level

We developed the spreadsheet simulation model based on consultation with NRCS, other ABC studies and current reported acreage of all almond orchard in the valley. The major input data include the following and their initial assumed values:

1. Total almond orchard acreage = 1.2 million acres
2. Total active harvesters on the field = 1,220 units
3. Average harvester speed used = 3 mph
4. Average new machine TSP emissions level = 22.6 lbs/acre (2,531 kg/km^2) (about 45% reduction across all machines)
5. Current % inventory of old machines = 55%
6. Current % inventory of new machines = 45%

The estimated 2018 TSP concentration level based on current inventory was set at 50.5 lba/acre (5,661 kg/km^2). Hence, the target level after 5 years would be around 25.3 lbs/acre (2,830 kg/km^2), equivalent to replacing around 10% of new harvest machines each year and following the best management practices for orchard floor preparation and proper harvest machinery setting adjustment. By 2025, the estimated TSP level should be around 22.3 lbs/acre (2,500 kg/km^2). This is way below the target of 25 lbs/acre (2800 kg/km^2).

Based on studies conducted in 2018, reduced dust generation may be achieve with the following management practices:

a. Proper preparation of windrow pile (excellent crown)
b. Proper preparation of orchard floor, free of grasses and debris
c. Proper machinery adjustment in terms of blower fan speed (as low as possible), lower harvester speed (close to 3 mph or less) and proper setting of depth of harvester setting (not too low and not too high).

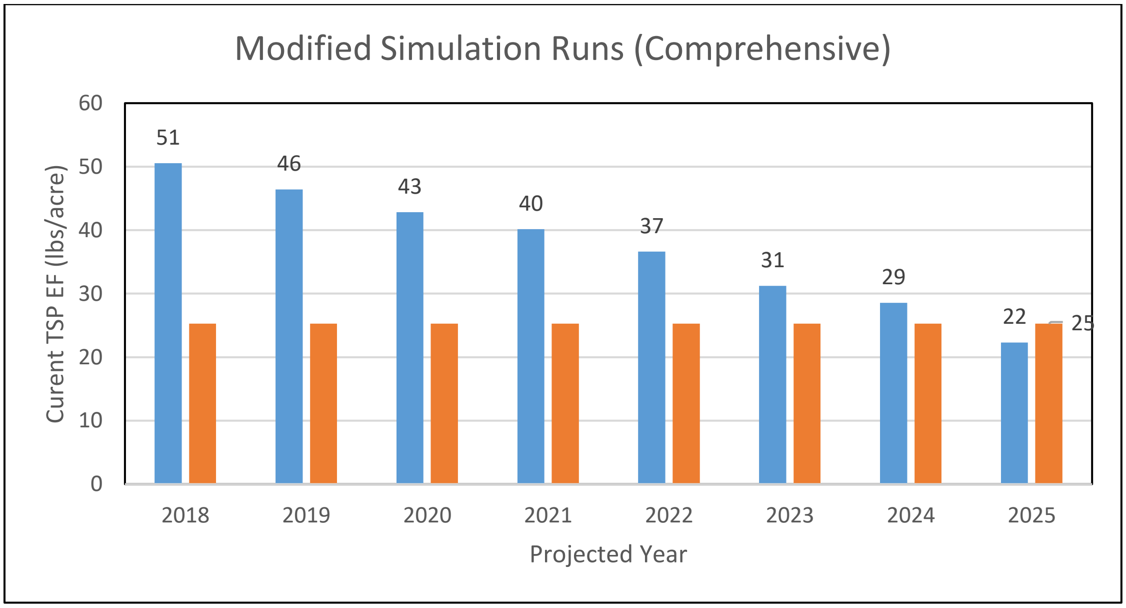


Figure 2. Results of simulation model runs combining the effect of new harvest machinery replacement and improve dust mitigation measures through proper machine adjustments and orchard floor preparations.

2. Dust Migrations Studies

The project conducted dispersion modeling with the use of EPA approved dispersion model AERMOD. The project then simulated the behavior of dust migration from the plantation towards the downwind areas, particularly to the exposed roads and nearby households. The study was conducted using dispersion modelling of TSP as source pollutant, with an averaged TSP emission factor of 6300 kg/km^2 for old machines and 2500 for new machines.

General Overview

An almond plantation in Dinuba, CA located at the corner of Rd 84 and Ave 388 was used for this study. The dusts coming from the plantation windrow during harvesting were simulated, each coming from the positions at the center and at the edges of the plantation. For each source position, the dusts were carefully simulated to estimate how far it will travel towards the downwind region. Dust migration maps were created to show the extent of dust exposure and estimate dust concentrations at the roadside and at the nearby houses. TSP concentration values are also shown at every contour lines of the map.

The dispersion modelling was based on the existing USGS topography maps and modelled using meteorological data on-site and available data from US meteorological agencies. The starting emission rate was based from a TSP average from the 3-day air sampling for that particular plantation.

At a given set of weather conditions, the wind speed was varied based on a user-defined category shown below:

Low (L):	0.5 – 2.0 m/s
Medium (M):	2.0 – 5.0 m/s
High (H):	> 5.0 m/s

Ambient T range considered: 30 – 35^{o} C
At these conditions, the position of the source emission was varied (center and edge) and dust migration was simulated to estimate the dust travel distance, the direction and the resulting TSP concentrations.

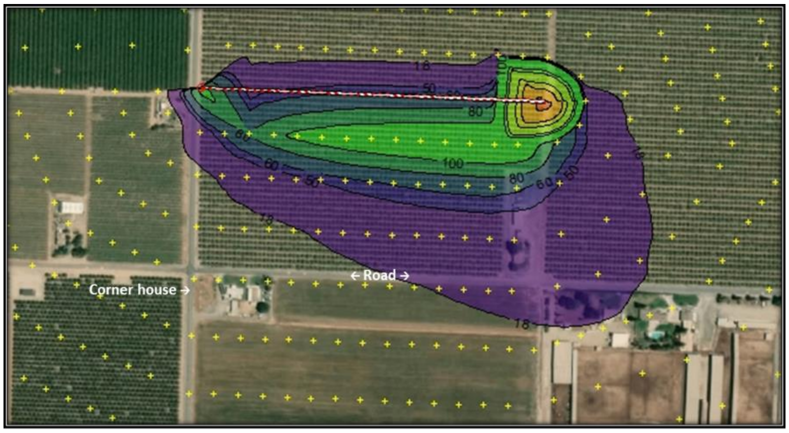
The dust migration study provides a general glimpse on how dust generated from harvesting affects the nearby areas of that particular plantation. However, the given dispersion maps are only valid for the given set of topographical and meteorological conditions. Different times of the day, plantation locations and other variables could produce different results.

Case Studies.

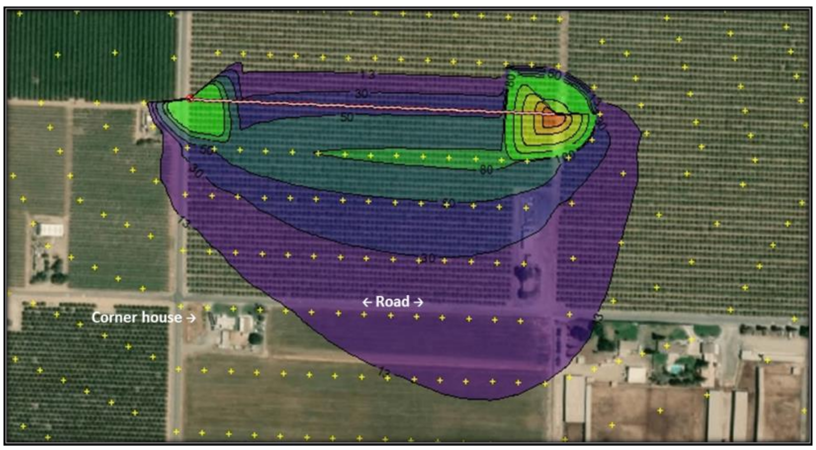
Case 1: **N → S** (dust to open field, road and house). Dust Source: Orchard Center
Case 2: **N → S** (dust to open field, road and a house). Dust Source: Orchard Edge
Case 3: **E → W** (dust to adjacent plantation, road and 2 houses). Dust Source: Orchard Edge

Figure 3 shows the site map and receptor distribution for Case 1. The figure also shows the real-time video capture of that event being simulated and modeled.

Figure 3. Site map and receptor distribution for Case 1 dust migration studies.



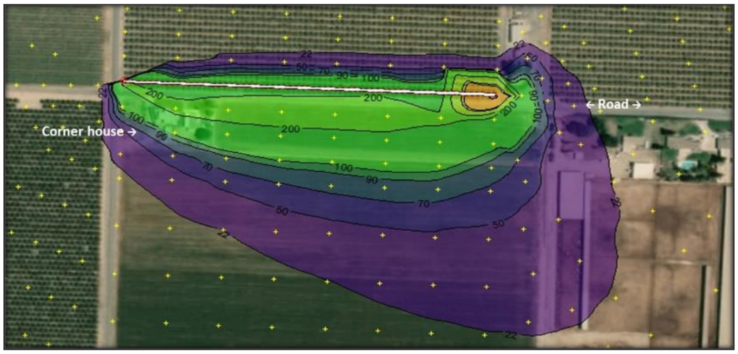
Wind Speed **(L)**
Max distance from Source (plantation center) = 428 m
Max TSP_{road} = 23.28 $\mu g/m^3$
Max $TSP_{corner\ house}$ = 4.11 $\mu g/m^3$



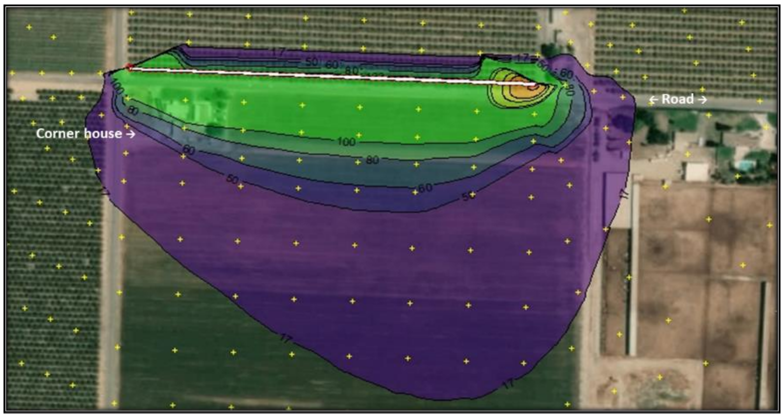
Wind Speed **(M)**
Max distance from Source (plantation center) = 510 m
Max TSP_{road} = 15.6 $\mu g/m^3$
Max $TSP_{corner\ house}$ = 10.50 $\mu g/m^3$

Wind Speed **(H)**
Max distance from Source (plantation center) = 320 m
Max TSP_{road} = 12.84 $\mu g/m^3$
Max $TSP_{corner\ house}$ = 5.52 $\mu g/m^3$

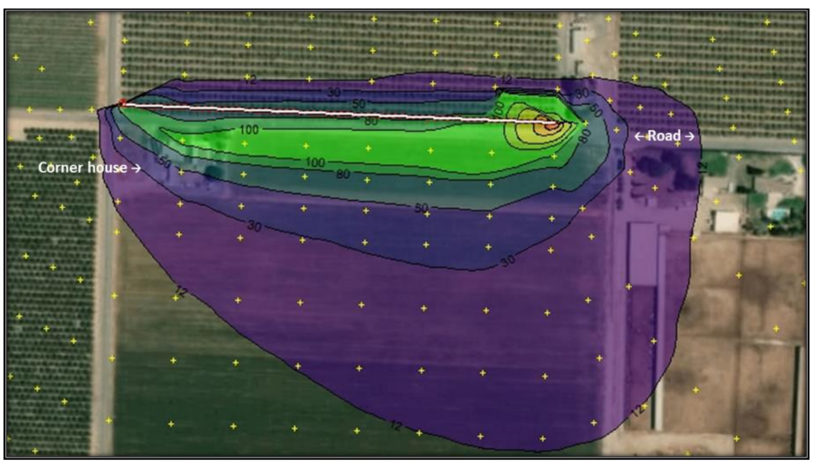
Figure 4. Results of dispersion modeling for Case 1 study showing migration of dust at low, medium and high wind speeds.



Wind Speed **(L)**
Max distance from Source (plantation center) = 280 m
Max TSP_{road} = 1270 $\mu g/m^3$
Max $TSP_{corner\ house}$ = 232 $\mu g/m^3$

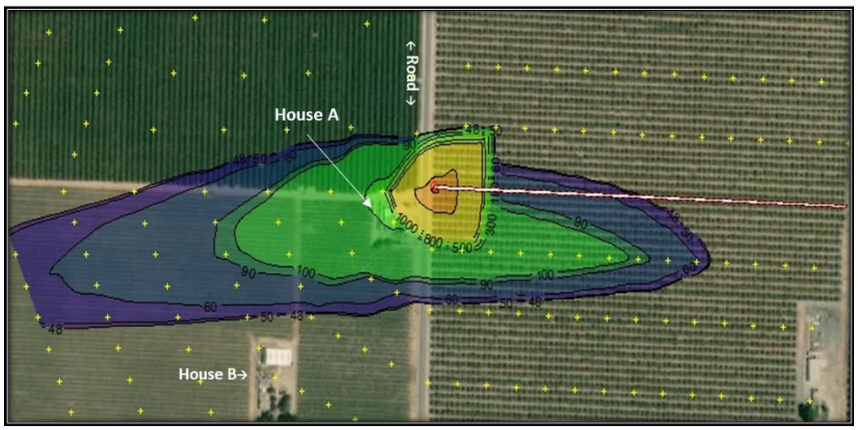


Wind Speed **(M)**
Max distance from Source (plantation center) = 310 m
Max TSP_{road} = 1030 $\mu g/m^3$
Max $TSP_{corner\ house}$ = 182 $\mu g/m^3$

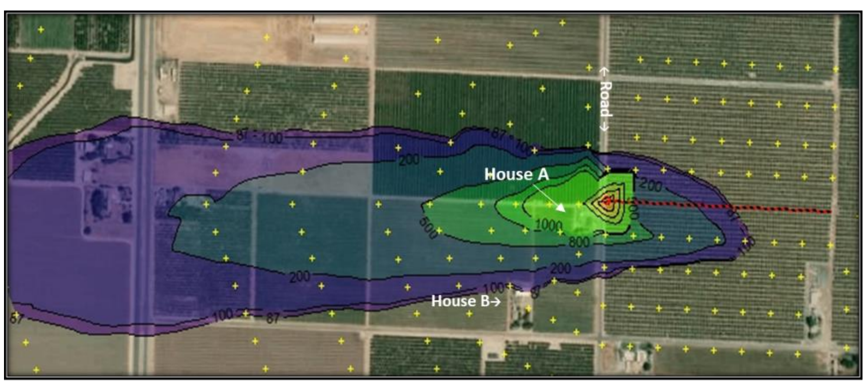


Wind Speed **(H)**
Max distance from Source (plantation center) = 262 m
Max TSP_{road} = 917 $\mu g/m^3$
Max $TSP_{corner\ house}$ = 108 $\mu g/m^3$

Figure 5. Results of dispersion modeling for Case 2 study showing migration of dust at low, medium and high wind speeds.



Wind Speed **(L)**
Max distance from Source (edge) = 621 m
Max TSP_{road} = 3000 µg/m^3
Max $TSP_{house\ A}$ = 1150 µg/m^3
Max $TSP_{house\ B}$ = 14.73 µg/m^3



Wind Speed **(M)**
Max distance from Source (edge) = 1890 m
Max TSP_{road} = 4750 µg/m^3
Max $TSP_{house\ A}$ = 2190 µg/m^3
Max $TSP_{house\ B}$ = 90.71 µg/m^3

Figure 6. Results of dispersion modeling for Case 3 study showing migration of dust at low, medium and high wind speeds.

Conclusions from this dust migration study:

- At high wind speeds, the dust tend to be more dispersed/scattered compared to dusts at lower wind speeds. Dust plume at less than 5 m/s are observed to be travelling in a more clustered and semi-uniform direction. This can be one of the reasons why the maximum distance travelled of dust at medium wind speed are slightly higher than that of high wind speeds (>5 m/s).
- The TSP concentration at wind speeds of 2-5 m/s do not really vary between each other (within a certain range) at a given harvesting position.
- When harvester is at the center of the plantation, the road side and the households are generally exposed to lower TSP concentrations and of no regulatory concern.
- However, TSP concentrations can be much higher when the harvester is at the windrows closer to the edge. This is therefore an item of concern if there are habitat near the orchard edge, but more importantly nuisance or human health. The TSP concentrations can be as much as 10-40 times as the harvesting comes closer to the orchard edge.

The dust migration study provides a general glimpse on how dust generated from harvesting affects the nearby areas of that particular plantation. However, the given dispersion maps are only valid for the given set of topographical and meteorological conditions. Different times of the day, plantation locations and other variables could produce different results.

Some management practices that we can summarize from the above studies are as follows:

a. The study discourages harvesting at very high wind speeds (> 5 m/s) if there are nearby communities and residential areas on the downwind side. Dust could travel more than 3 km (1.9 miles)
b. Operator should harvest early morning or late in the afternoon when the wind speeds are rather low (less than 2 m/s) if possible.
c. At medium wind speeds (2-5 m/s), operator should remember the wind direction. If there are inhabitants on the downwind portion of the orchard. Dust at these level could travel to about 1.9 km (1.2 miles), especially when harvesting at the edge of the orchard.

3. Evaluation of Quick Measurement Techniques

Table 2 shows the results summary comparing EPA Method 9 and EPA Alt 082. The two methods correlate very well. EPA Method 9 data showed more conservative opacity readings than the EPA Alt 082. The trend is quite remarkable between these two simple methods. The highest dust reductions occured on treatment with no fan. Eliminating the fan blower will reduce the visible dust emissions between 57-66% with an average of around 61.5% reduction. The least dust reduction occurred with low vehicle speed and low flow with a reduction of only 15%.

A better visual display of comparative TSP values between EPA Method 9 and EPA Alt 082 is shown in Figure 7. The control readings are always higher than treatments. Intuitively, the data of EPA Alt 082 makes more sense relative to the treatments. The new harvester had an average of 55% reduction and correlates well with previous year's study using FRM samplers. Hence, the use of these simple visible dust measurement techniques had very high confidence of acceptance relative to the tedious methods employed when FRM samplers are used.

The project also developed a simple correlation between the new quick methods and TSP values. These values correlate well with the data presented earlier with old machines having an emission factor of around 56.3 lbs/acre (6300 kg/km^2) and its equivalent opacity value is around 26 (per average of EPA Method 9 and EPA Alt Method 082). Newer machines whose settings are optimized will have an EPA Method 9 (or EPA Alt 082) value of around 14 which is equivalent to a TSP emission factor of 22.3

lbs/acre (2500 kg/km^2). Hence, the study established values for visible dusts concentrations even if these quick methods were used to keep track of current level of visible dust in the valley for almond harvest operations. The only data that is inconsistent is the results from high speed-standard adjustments. This is contrary to previous results and may not be valid for this experiment. Note that, all experiments are compared with Flory 480 against the new machine of Flory. However, in previous studies, a different Flory Model was used for what is considered new machine. Hence, there will be some minor discrepancies.

Table 2. Data of Opacity for EPA Method 9 and EPA Alt Method 082.

Treatments and Control	EPA Method 9		EPA Alt 082	
	Opacity	% Lower	Opacity	% Lower
1. Control	23.28	0%	29.00	0%
2. No Fan	7.84	66%	12.50	57%
3. New Machine Standard	13.94	58%	14.09	51%
4. High Speed Standard	11.65	50%	17.50	40%
5. Low Speed/Height	17.06	40%	17.50	40%
6. High Speed/Low Flow	9.68	27%	22.00	24%
7. Low Speed/Low Flow	19.79	15%	25.00	14%

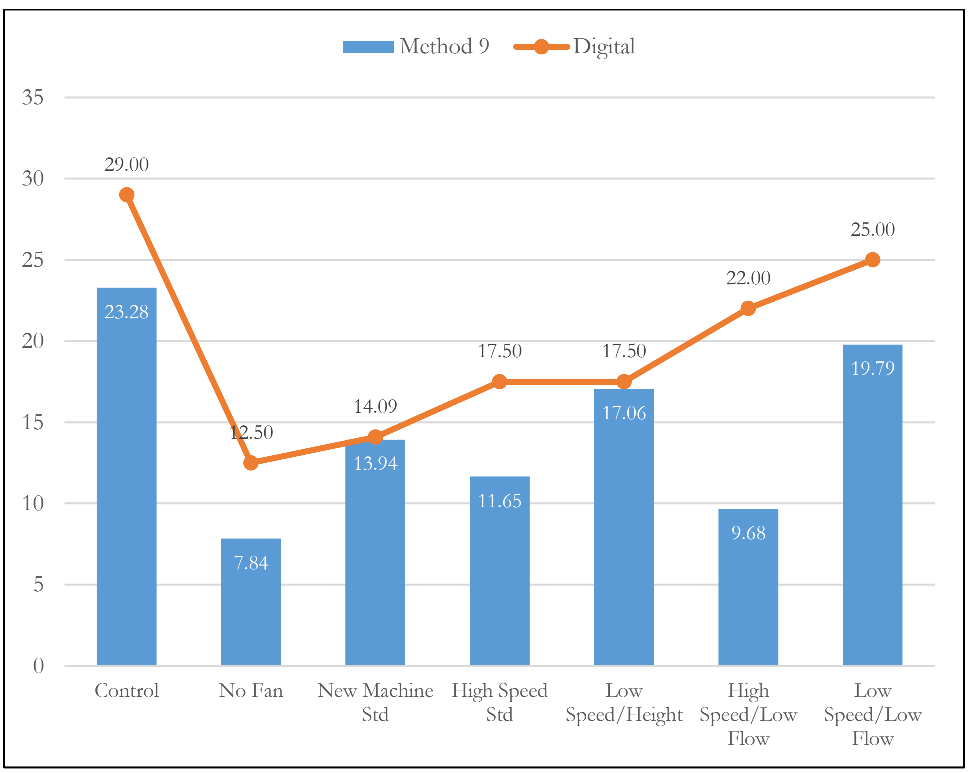


Figure 7. Plot of comparative opacity data between EPA Method 9 and EPA Alt Method 082.

4. Dust Reductions Level Through Changes in Machinery Adjustments

The study has established a robust database on dust reductions based from this years study as well as previous research projects funded by the Almond Board. These correlations will be used in future studies to provide updates on target visible dust level in the valley. In fact, even survey data conducted by the Almond Board each year may also be converted into numbers or values, both for opacity readings based on EPA Method 9 and Alt 082 as well as TSP concentrations or emission factors.

The study proposes to average the EPA Method 9 studies as well as EPA Alt 082 as shown in Table 3 below and their corresponding TSP values. Currently, the study has established a simple relationship between TSP and opacity values reported by either EPA Method 9 or EPA Alt 082 and is shown by the predicted Equation (1) in units of kg/km^2. To convert the units of kg/km^2 into units of lbs/acre, one would simply divide the TS values in 112 as shown in the convertion Equation 2.

$$TSP\ \left(\frac{kg}{km^2}\right) = 316.67 \times Opacity - 1929.3 \qquad \text{Equation (1)}$$

$$TSP\left(\frac{lbs}{acre}\right) = \frac{kg}{km^2} \times \frac{2.2\ lbs}{1\ kg} \times \left(\frac{1\ km}{1{,}000\ m}\right)^2 \times \left(\frac{1\ m}{3.28\ ft}\right)^2 \times \frac{43{,}560\ ft^2}{1\ acre} = \frac{1}{112} \qquad \text{Equation (2)}$$

Table 3. Recommended values of opacity and its coresponging TSP values.

Treatments and Control	EPA Method 9/EPA Alt 082		TSP Values	
	Opacity	% Lower	lbs/acre	Kg/km^2
1. Control	26	0%	56.3	6,300
2. No Fan	10	61.5%	11.0	1,237
3. New Machine Standard	14	46.2%	22.3	2,500
4. High Speed Standard	14.6	43.8%	24.0	2,694
5. Low Speed/Height	17.3	33.5%	31.7	3,549
6. High Speed/Low Flow	15.8	39.2%	27.4	3,074
7. Low Speed/Low Flow	22.4	13.8%	46.1	5,164

Note that there are still discrepancies among the treatments used for this study. A new machine running at higher tractor speed of 5 mph would have lower emission factor than a new machine operated at standard travel speed of 3 mph. In this case, speed of travel may not be a contributing factor on emissions. The other results are rather intuitive, that is, the lowest emission factor is when the blower is not in operation (or no fan). Unfortunately, operators would not do this simply because of their intuition that this will carry too much dust on the harvest truck. The low harvester speed coupled with low blower speed setting only reduced emission factor by 13.8% which is not very intuitive. Hence, more studies are warranted to establish these correlations based on these simple methods of evaluating visible dust levels during almond harvest operations.

5. Summary of Best Management Practices Identified

The current study has validated previous results that shows old harvesters will have the highest visible dust emissions compared with new machines by about 50% reduction. Not operating the fan/blower will results to having the lowest emission factor by more than half (61.5%). Operating a new harvester at higher travel speed with the correct setting will also result to reduced emission factor based from this study. However, this is contrary to our previous research results. As explained earlier, we have used a different Flory Model for a new machine. Likewise, operating a new harvester at higher travel speed coupled with low fan or blower setting will also result in further reduction in dust emission factor. The low travel speed coupled with low fan or blower rpm resulted in higher emission factor than the emission factor of a new machine, which does not follow with usual inference and hence, needs to be further evaluated. Some chealer methods may not be consistent or dependable. As we generate more research studies, our confidence in these conclusions will be made firm.

The project further developed a more robust simulation spreadsheet to account other known best management practices as follows:

a. Reduced number of harvester passes
b. Reduced sweeping passes
c. Proper harvester depth settings
d. Lower fan speeds
e. Proper orchard floor preparations
f. Wetting of roads to reduce fugitive dusts
g. Use of other dust suppressing additives

The study is now developing correlations with these best management practices to convert survey data of the orchard owner's practices and compare this to the visible dust emissions target each year.

Summary and Conclusion. This study has the following conclusions.

The project has recommended the 2018 baseline TSP emission factor of 50.5 lbs/acre (5,658 kg/km^2). The 2025 target TSP emission factor should be around 50% of this value or around 25.3 lbs/acre (2,830 kg/km^2). The project hopes to use all its previous research results each year to provide a meaningful new TSP values in the valley through either actual sampling using these new measurement techniques or even convert survey data into numeric values of either TSP, opacity or even other regulated particulate matter.

The study also developed simple correlation between weather conditons as well as dust migration and has made several recommendations for the harvest machinery operator if there are some sensitive areas within the vicinity of the orchard. The operators will simply be aware of wind speed and direction in the area and use common sense during actual harvest period. At high wind speed, dust could travel as much as 2 miles. Hence, they should harvest during lower wind speeds as well as wind directions in uninhabited places.

The project identified three simple dust measurement techniques and recommended its use by the Almond Industry to aid in long-term visible dust reduction. These simple methods include the following:

a. EPA Method 9 Visual Emissions Evaluation
b. EPA Alt Method 082 Digital Camera Opacity Techniques, and
c. Laser PM Instruments mounted on drones (i.e., measured from drones high above the canopy of the orchard).

The study is not recommending the use of opacity meters placed on orchard rows due to safety and inconsistency of results.

The study further developed correlations among the various techniques and recommends the baseline TSP values as guide to address the goal of 50% dust reduction by the year 2025.

The study developed a spreadsheet simulation model to make projections on how well the industry addresses the yearly goals. The recommended TSP emission factor for old machine was 56.3 lbs/acre (6,309 kg/km^2) (or nominal 56 lbs/acre or 6,300 kg/km^2) and the new machine TSP was 22.4 lbs/acre (2,514 kg/km^2) (or nominal 22 lbs/acre or 2500 kg/km^2). The group will collate all available inventory of old and new machines each year and improve the spreadsheet model. The model will be updated yearly and the group will report the progress each year to the industry.

The proposed plan was to achieve 10% new machinery replacement each year and implement all the best management practices for both orchard management and machinery adjustment. The group will also identify new best management practices each year, recommend to orchard machinery operators to speed up the target and achieve 50% reduction prior to year 2025.

Recent Research Effort Publications:

We have submitted a technical paper for last year's work for review in a refereed journal (Journal of Air and Waste Management Association, JAWMA). It was published on Setember 9, 2019. The citation is as follows:

> El Jirie N. Baticados, Sergio C. Capareda & Amado L. Maglinao (2019) Particulate matter emission factors using low-dust harvesters for almond nut-picking operations, Journal of the Air & Waste Management Association, 69:11, 1304-1311, DOI: 10.1080/10962247.2019.1655500.

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